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JOSEPH A. HOLMES, Director

FULLER'S EARTH

BY

CHARLES L. PARSONS



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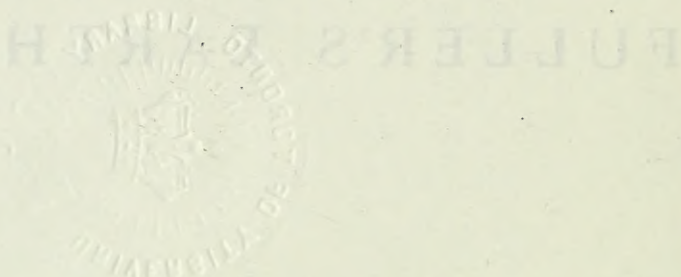
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FULLER'S EARTH.

By CHARLES L. PARSONS.

INTRODUCTION.

The United States produces all of the fuller's earth used for refining petroleum within its borders. On the other hand, most of the fuller's earth used in bleaching edible oils has been imported from England. Recently a few of the refiners of cottonseed oil have begun to utilize domestic fuller's earth, whereas others have been unable to substitute it successfully for English earth in their practice. Many samples of American earth distinctly superior in bleaching power to the English earth have come to the attention of the Bureau of Mines. For these reasons an investigation of the mining, preparation, and use of fuller's earth in this country, especially in its application to edible oils, was conducted in order to ascertain why our own raw material has been deemed inapplicable to our needs.

During the calendar year 1912, according to figures of the United States Geological Survey,^a there were imported into the United States 1,970 tons of unground fuller's earth, valued at \$11,619, and 17,139 tons of ground fuller's earth, valued at \$133,718, these values being based on the wholesale market price at the port of origin. The addition of transportation charges, commissions, etc., make the price to the American refiner \$14.50 to \$16 per ton. According to the latest figures compiled by the United States Geological Survey,^b the United States in 1912 produced 32,715 tons of fuller's earth, valued at \$305,522, or \$9.34 per ton, at the mine. Most of this domestic production was from three plants in Florida and one in southwestern Georgia and was used almost wholly for decolorizing petroleum. A small amount from other localities was used in the refining of edible oils. No figures definitely differentiating fuller's earth from other clays are kept in regard to our exports, but it is certain that several thousand tons of domestic earth was exported to Germany, and it is also true that German refiners of edible oils have

^a Mineral Resources, U. S., 1912: U. S. Geol. Survey, 1913, Fuller's Earth, advance chapter, p. 5.

^b Ibid., p. 7.

used and are using large quantities of American fuller's earth and have a higher appreciation of its merits than our own refiners.

* As a result of the investigations made, the Bureau of Mines believes that the United States has fuller's earth far better suited for refining edible oils than any imported, and that to assure the almost universal use of this earth by American refiners there is required only a careful and intelligent technical control of the preparation of the output and its application to the bleaching of oils.

HISTORY OF THE FULLER'S-EARTH INDUSTRY IN THE UNITED STATES.

Fuller's earth was first used for "fulling" or removing grease from woolen goods and takes its name from the process. At present this use, owing to the cheapness of good soap, has almost wholly ceased. Figures as to imports from 1867 to 1899 may be found in an article by David T. Day,^a and since 1899 in the reports of the United States Geological Survey. Fuller's earth seems to have been first used in this country for refining edible oils about 1878 or 1880. According to David Wesson^b it came to be used for this purpose through investigations undertaken on account of a statement that reached N. K. Fairbanks & Co., of Chicago, to the effect that in the Orient olive oil was sometimes improved in color by agitating it with clay. Various samples of clays were tried with cottonseed oil and the clay then used for fulling cloth in England gave much better results than any other clay that the company was able to obtain.

In 1891 fuller's earth was discovered in Arkansas by John Olson, who still mines earth near Benton, Ark. In 1893 fuller's earth was discovered at Quincy, Fla., which proved to be especially applicable to the bleaching of petroleum. The deposits near Quincy, together with others in the neighboring parts of Florida and southwestern Georgia, have from that time furnished all of the fuller's earth used in the refining of mineral oils in this country. The Florida earths have, however, never been extensively applied to the bleaching of fats and vegetable oils. The Arkansas earth is used wholly for edible oils.

Since the discovery of the Florida earths many other deposits of clays with marked bleaching power have been found in other States.

DEFINITION OF FULLER'S EARTH.

Fuller's earth is a variety of clay that has high capacity for adsorbing basic colors and can remove these colors from solution in

^a Day, David T., The occurrence of fuller's earth in the United States: Jour. Frank. Inst., vol. 150, 1900, p. 219.

^b Wesson, David, The bleaching of oils with fuller's earth: Min. and Eng. World, vol. 37, 1912, p. 667.

animal, vegetable, or mineral oils, as well as from some other liquids, especially water. It is valuable when its adsorptive powers are strong enough to permit it to compete actively with fuller's earth already accepted as of standard quality for refining oils.

CHEMICAL COMPOSITION OF FULLER'S EARTH.

Analyses of various samples of fuller's earth vary so greatly that chemical analyses are now well understood to be no criterion whatever in determining whether or not a particular clay shall be classified as a fuller's earth.^a Like all other clays, fuller's earth is a hydrous, aluminium silicate containing small proportions of other substances. Most fuller's earths contain a higher percentage of water of composition than most clays, but this water is not an essential factor in the bleaching properties of all fuller's earths; some bleach fully as well after it has been driven off as before, and others lose much of their bleaching power when this water is removed.

OCCURRENCE OF FULLER'S EARTH IN THE UNITED STATES.

Fuller's earth is found in quantity in Georgia, Florida, South Carolina, Alabama, Arkansas, California, and Texas; and deposits have been reported from Colorado, South Dakota, New York, and Massachusetts. With the exception of the fuller's earth found in Arkansas, all of the deposits are of sedimentary origin. The Massachusetts deposit is a glacial silt and is the only glacial silt known to be so classified. The Arkansas deposit is unique, in that it is found in place in regular veins and according to Miser^b has been derived from basaltic dikes.

With the exception of the Arkansas deposits, all known American deposits of fuller's earth occur under much the same conditions as any clay bed, and have more or less overburden which must be removed before the fuller's earth can be mined. Usually a bed is distinctly stratified and very thin layers of sand separate the layers of earth which may be several inches thick. The geology of the

^a Vaughan, T. W., Fuller's earth deposits of Florida and Georgia: U. S. Geol. Survey Bull. 213, 1903, p. 399; Porter, J. T., Properties and tests of fuller's earth: U. S. Geol. Survey Bull. 315, 1907, p. 271; Sellards, E. H., and Gunter, Herman, The fuller's-earth deposits of Gadsden County, with notes on similar deposits found elsewhere in the State: 2d Ann. Rept. Florida Geol. Survey, 1908-9, p. 258; Aubury, L. E., The structural and industrial material of California: California Min. Bur., Bull. 38, 1906, p. 273; Day, David T., The occurrence of fuller's earth in the United States: Jour. Frank. Inst., vol. 150, 1900, p. 220; Wesson, David, The bleaching of oils with fuller's earth: Min. and Eng. World, vol. 37, 1912, p. 667.

^b Miser, H. D., Developed deposits of fuller's earth in Arkansas: U. S. Geol. Survey Bull. 530, 1911, p. 207.

Florida earths has been described by Vaughan^a and others.^b The geology of the South Carolina deposits is mentioned by Sloan^c and that of the Georgia deposits by Veatch;^d but the Georgia and South Carolina deposits have never been fully mapped or described. The geology of the Arkansas deposits is discussed by Miser,^e and that of the Texas deposits by Duessen,^f and the deposits at Lawrence, Mass., are described by Alden.^g

The Florida deposits are mainly in Gadsden County, near Quincy; the southern Georgia deposits are across the State line from Quincy; other Florida deposits are at Ellenton, in Manatee County, on the west coast of southern Florida. Though the Florida deposits are much like any other in mode of occurrence, they are used almost wholly on mineral oils and are distinctly different from the fuller's earths of central Georgia and South Carolina. The deposits in southern Florida lie below the level of the sea and are within a few hundred feet of the shore, whereas those in northwestern Florida, except such as are in the bed of some stream, are high lying and are easily drained. The deposits of central Georgia are in a different geological formation from those of Florida, and the largest and best deposits are on high ground and are comparatively dry.

In all of the States the beds of fuller's earth vary greatly in extent and thickness, some being only a few inches thick and others as much as 25 feet thick. All are covered by sand or clay, the thickness of the overburden varying with the character of the topography. Deposits of the material are plentiful, but comparatively few contain sufficient material of such quality and are so situated with reference to mining and transportation costs that their exploitation would prove commercially successful.

In Georgia large deposits occur in Twiggs and Wilkinson Counties, especially at Pikes Peak some 12 miles southeast of Macon; at Groveton near Augusta; in Colquitt County near Moultrie; and in Pulaski County, where they underlie most of the country between Coleys Station and Longstreet; in the region adjacent to Gadsden County, Fla., and undoubtedly in many other localities not reported.

^a Vaughan, T. W., Fuller's-earth deposits of Florida and Georgia: U. S. Geol. Survey Bull. 213, 1903, pp. 392-396.

^b Sellards, E. H., and Gunter, Herman, The fuller's-earth deposits of Gadsden County, with notes on similar deposits found elsewhere in the State: 2d Ann. Rept. Florida Geol. Survey, 1908-9, pp. 255-290.

^c Sloan, Earle, Fuller's earth: South Carolina Geol. Survey, Series 4, Bull. 2, 1908.

^d Veatch, Otto, Second report on the clay deposits of Georgia: Georgia Geol. Survey Bull. 18, 1909, pp. 207, 309, 317, 371.

^e Miser, H. D., Developed deposits of fuller's earth in Arkansas: U. S. Geol. Survey Bull. 530, 1911, pp. 208-216.

^f Duessen, Alex., Notes on some clays from Texas: U. S. Geol. Survey Bull. 470, pt. 2, 1910, pp. 337-351.

^g Alden, W. C., Fuller's earth and brick clays near Clinton, Mass.: U. S. Geol. Survey Bull. 430, 1910, pp. 402-404.

In South Carolina there is a deposit of great extent in Williamsburg County near Salters Depot, another in Dorchester County near Summerville, and still another in Sumter County near Sumter.

The Arkansas deposits are all some 7 miles south of Benton, and unlike any other known deposits of this material are found in regularly defined veins that dip from 45° to almost 90° . In this locality are numerous veins and several have been mined, one to a depth of 140 feet.

In Texas deposits have been reported from several places, notably near Summerville, West Point, and Burton.

In California deposits of fuller's earth have been mined at Vacaville and Bakersfield. Other deposits have been found in that State.

In Massachusetts deposits are mined at Lancaster, and this earth is used wholly in the place of alkali to remove surplus dye from woolen goods. Deposits in other States need not be considered here, as they have not made a regular production.

PLANTS VISITED.

In the course of this investigation the following plants were visited, the operation of which afforded every facility for examining deposits, methods of preparation, cost of production, and the difficulties which had been encountered in marketing the product: General Reduction Co., Atlanta, Ga., mines at Pikes Peak, Ga.; Atlantic Refining Co., Philadelphia, Pa., mines at Ellenton, Fla.; Lester Clay Co., Jacksonville, Fla., mines at Attapulugus, Ga.; Florida Fuller's Earth Co., Ellenton, Fla.; Fuller's Earth Co., Midway, Fla.; American Meat Packers' Association, Chicago, Ill., mine at Fairplay, Ark.; American Refiners' Earth Co., Benton, Ark., mine at Klondike, Ark.

Other plants were not visited owing either to the fact that they were at the time inoperative or to other reasons. However, the National Fuller's Earth Co., mines at Salters Depot. S. C.; the Fuller's Earth Co., Houston, Tex., mines at Summerville, Tex.; the Western Fuller's Earth Co., mines at Vacaville, Cal.; and the J. E. & R. N. Farnsworth Co., mines at Lancaster, Mass., cooperated cordially by furnishing information and granting permission to visit their mines. Samples of earth produced by the Floridin Co., which has two mines near Quincy, Fla., and is one of the largest producers of fuller's earth for the refining of petroleum, were not included in the bleaching tests; neither were the company's methods studied, as it did not wish to cooperate by allowing a representative of the bureau to view its operations.

Samples of fuller's earth from the following deposits were investigated and will be referred to in this paper under the numbers given:

List of fuller's-earth samples examined.

Number of samples.	Source of earth.	Operating company.
1	Summerville, Tex.	Fuller's Earth Co.
2	Vacaville, Cal.	Western Fuller's Earth Co.
3	Southern California (exact locality unknown)	
4	do.....	
5	do.....	
6	do.....	
7	English earth received in lump form	
8	Sumter, S. C.	
9	Moultrie, Ga.	
10	Pikes Peak, Ga.	
11	do.....	General Reduction Co.
12	Fitzpatrick, Ga.	
13	Sent from Atlanta, Ga. (exact locality unknown).	
14	Ellenton, Fla.	Atlantic Refining Co.
15	do.....	Florida Fuller's Earth Co.
16	Attapulgus, Ga.	Lester Clay Co.
17	Midway, Fla.	Fuller's Earth Co.
18	English earth, IXL brand (as imported)	
19	Fairplay, Ark.	American Meat Packers' Association.
20	Klondike, Ark.	American Refiners' Earth Co.
21	Lancaster, Mass.	J. E. & R. N. Farnsworth.
22	Fort Payne, Ala.	
23	Andalusia, Ala.	

EXPORTS OF FULLER'S EARTH.

As fuller's earth is usually exported as clay, no definite figures are procurable as to shipments abroad. From information received, however, it is evident that several thousand tons annually are now sent to Germany, and representatives of German firms have stated to the author of this paper that they found the American earth far superior to any other they can procure for refining both edible oils and petroleum. For the information of American producers, a list ^a of German firms interested in fuller's earth is given below.

List of German firms using fuller's earth.

IMPORTERS.

Rudolf Kroseberg, Ludwigskirchplatz 12, Berlin.
Meyer Cohn, Hanover.
Adolf Thol, Hanover.
Oelwerke, Stern Sonneborn, Actiengesellschaft, Hamburg.
Max Bülow, Berlin W. 62, Wormerstrasse 6.
B. Groverman & Co., Bremen, Ansgarukirchhof 1.
Adolf Achenbach, Köln a. Rh.
Deutschen Fuller-Erde-Werke, Hamburg.

^a This list was procured in part from the records of the Bureau of Manufacturers, Department of Commerce.

CONSUMERS.

Hirsch & Merzenich, Grenzhausen, Hessen-Nassau.
Buch & Landauer, Melchiorstrasse 4, Berlin.
Wilh. Giessmann, Wurzen.
Herm. Meininghaus, jr., Dortmund.
W. & H. Melsbach, Krefeld-Linn (Rhein).
M. Gottschalk Sohne, Charlottenburg-Berlin.
Dr. Max Lehmann & Co., Elisabeth-Ufer 5, Berlin.
J. G. Mouson & Co., Frankfurt a. M.
Stettiner Kerzen & Seifenfabrik, Stettin.

PROPERTIES OF FULLER'S EARTH.

Though samples of fuller's earth from different parts of any one deposit, or indeed from any one locality, are much alike, samples from different localities are so different in their physical properties that it is by no means easy to classify them. To determine whether or not a particular clay is a fuller's earth is no simple matter, for its bleaching power is practically the only characteristic by which it may be identified. Among the properties formerly attributed to fuller's earth are nonplasticity, disintegrating in water, detergent action, large water content, and the property of adhering to the tongue.

It is quite true that most fuller's earths are nonplastic, and that none have been found which are plastic enough to be of value in the ceramic arts; on the other hand, certain earths are distinctly plastic when worked with large proportions of water. A few fuller's earths do disintegrate in water, and indeed the material from Lancaster, Mass., requires no grinding, as it falls to powder when dry. Again, certain fuller's earths are almost as hard as slate and are as little affected by water. Certain fuller's earths do show distinctly a detergent action, whereas others are harsh in feel both wet and dry. Most dry fuller's earths, on account of their porosity, adhere strongly to the tongue, but other clays show the same property. The foliated structure so strongly apparent in fuller's earth in most of the South Atlantic States is little or not at all seen in other deposits, and where the material is in veins or is moist and semiplastic the foliation may be entirely absent.

The shades of color of fuller's earth are fully as great as those of other kinds of clay. Most of the earths on the market are light brown, gray, buff, or cream color, and a few are almost white. All fuller's earths which have been found valuable for bleaching purposes show a distinct so-called acid reaction. If a sample is touched to neutral litmus paper the paper will be turned red; if the clay is suspended in water and phenolphthalein is added, a quantity of alkali, which varies widely with different earths, can be added before

the red color appears. This property is no indication of true acidity, for the earth contains no acid. The same power that enables the earth to adsorb basic colors enables it to adsorb true bases also, and to prevent their reaction becoming evident until the adsorptive power of the earth has been satisfied.

The degree of "acidity," or adsorptive power for bases in solution in water, is no definite criterion of the power of the earth for adsorbing bases or colors from solution in oil. Accordingly, the bleaching power of fuller's earths for oils is by no means proportional to the ability of the earths to remove bases in solution in water. The degree of "acidity" is, however, directly proportional to the power that most fuller's earths have of removing basic colors from solution in water.

All fuller's earths adsorb basic colors in solution in oil or in water. Their commercial value, however, depends upon the power of removing these colors from solution in oil, which, as already pointed out, is by no means the same as removing these colors from water. The power of removing basic colors from water has found application only in the woolen industry and in the production of cheap pigments for paper.

The range of specific gravity of fuller's earth is much the same as that of other clays, although the apparent specific gravity varies widely, owing to variations in porosity. Fuller's earth, as a rule, is lighter and more porous than other clays. However, both the English earth and the Arkansas earth, when dry, are fully as dense as ordinary clay. The volume that a given weight of fuller's earth occupies varies widely, and a cubic foot of dry, ground fuller's earth from Georgia or Florida weighs only a little more than half as much as a similar volume of English or Arkansas earth. This fact should be taken into careful consideration in applying fuller's earth to the bleaching of oils, for if the same measures are used in a comparative test of different fuller's earths no valid conclusions can be reached. Specific volumes of the fuller's earths studied in this investigation will be found on page 29.

Most samples of fuller's earth give more or less taste and odor to edible oils but they vary greatly in this respect. For many years the English earth was preferred chiefly because it gave little effect, but methods for removing taste and odor are now well known to all oil refiners, so that the question is not so important as formerly.

Why taste and odor should be imparted to oil by fuller's earth is not known, but it certainly is not generally due to any soluble material in the earth, but rather to some oxidizing action upon the oil itself. This property appears to be connected with the "acidity" of the earth, for if fuller's earth is treated with lime water this action is greatly reduced. Unfortunately, the bleaching power is destroyed

at the same time. Certain fuller's earths have so marked an oxidizing action on edible oil that they cause the oil to catch fire spontaneously when air is blown through the filter presses to remove the adhering oil, as is always done in practice. This property is fatal to the use of a fuller's earth in refining edible oils, for beside fire risks to buildings it invariably destroys the cloths of the filter presses. Fortunately, only earth from one or two deposits has this property highly developed. This is apparently one of the reasons why some of the Florida deposits have not been successfully used in the treatment of edible oils, as David Wesson^a speaks particularly of the Quincy earths as having this characteristic.

MINING OF FULLER'S EARTH.

With the exception of the Arkansas deposits, fuller's earth is mined like brick clay. The cost of mining depends chiefly upon the magnitude of the operations and the depth of overburden to be removed.

In small mines the material is almost always removed by pick and shovel, with the help of scrapers drawn by horses. In two of the larger mines overburden is removed with steam shovels, and in yet two others a steam scraper is utilized. If many thousand tons of overburden is to be removed in the course of a year, the installation of machinery will greatly reduce the cost of removal per yard. After the overburden is removed, the fuller's earth is dug with pick and shovel and is loaded on cars or small carts according to the quantity of material being mined. The foliated character of many of the deposits makes this work comparatively easy, as the material tends to break in blocklike forms, which naturally facilitates mining.

As the blocks dry the thin layer of sand found between many of the substrata tends to fall away so that it does not interfere with future operations. The earth is then drawn by engine, cable, or horses to the bins, from which it falls or is shoveled to the crusher hoppers. In many of the mines the removal of water is at times a troublesome problem, and in these mines the fuller's earth normally contains a much higher proportion of water to be removed in the driers. As all fuller's earth takes up water easily whenever it comes in contact with it from rains or otherwise, the removal of water is always a costly item in the preparation of the material.

In Arkansas, on account of the character of the deposits, open-cut methods of mining can not be used. Vertical shafts are sunk, cross cuts run to the vein, drifts are driven along the vein, the earth is stoped down and then hauled to the surface in large buckets. The mines are easily timbered and as yet no serious accidents have been

^a Wesson, David, The bleaching of oils with fuller's earth; Min. and Eng. World, vol. 37, 1912, p. 667.

reported. The material is drawn in wagons from the mouth of the shaft a few hundred yards to the mill, which is situated within a few feet of the railroad.

In England the preparation of fuller's earth for the mill differs from American practice. No American earths require, nor can be prepared by, the same method that is applied to the English. In England the material is dug and is then separated from sand and small stones by elutriation, much as some kaolins are prepared in this country. The clay is then either settled or run through filter presses and dried, being plastic enough to form into hard lumps capable of grinding. American earths are so pure as mined that they require no extensive separation from foreign material and when dried can be ground directly.

MILLING PRACTICE.

Milling practice in fuller's earth plants in this country comprises simply drying, grinding, and bolting, and differs in detail at every plant that was visited. As milling is of the utmost importance, it will be discussed here in some detail.

CRUSHING AND DRYING.

The lump material as brought to the mill usually contains so much water that its first crushing and drying is by no means easy. If the large lumps are kept under cover in well-ventilated bins or on floors they dry in time, so that milling becomes comparatively easy, but the cost of double handling and the time required seem to demand, in present practice, that the material be run almost immediately into the crushing rolls and broken up into small lumps about the size of stove coal.

In one large plant the material instead of being crushed with rolls is run into a brick machine and shaped into bricks that are carried on cars through a tunnel drier through which hot air is forced. Seemingly, the best form of crushers consists of two sets of rolls, one corrugated and one toothed, one above the other. The material from the first set of rolls goes immediately to the second. Mechanical conveyors lift the crushed material from the rolls to the driers. It has generally been held that in drying fuller's earth for bleaching edible oils great care must be taken not to remove the combined water, and accordingly the fuller's earth produced for this purpose is now dried either in tunnel driers, as above described, or in rotary driers constructed with especial reference to avoid overheating the material. In one plant a special home-constructed drier, consisting of tubes externally heated by steam, through which the earth is drawn by conveyors, appeared to give very efficient results.

Although it is true that the bleaching power of English earth is distinctly impaired by the removal of the combined water, all earths are not similarly affected, and some of the American earths bleach fully as well after all of the combined water is removed, so that extreme care to prevent overheating is by no means so important with certain earths as it is now thought to be.

In the drying of fuller's earth for bleaching petroleum, overheating is not to be feared, except as the temperature approaches the softening point of the clay itself. At the plants in Florida the earth is dried in rotary driers heated directly by a petroleum burner. These driers are ordinarily about 40 feet long by 6 feet in diameter and almost every style on the market is used. In one mill the heat is applied where the wet earth enters the rotary, in another at the discharge end of the drier. The speed of the drier and the rate of feed are so regulated that the material discharged is dry enough for grinding and can be carried by the conveyor directly to the mill. In some instances the earth is passed through small crushers of the "corn cracker" type before the final drying.

The types of grinding mills used are almost as numerous as the plants producing the material, almost every type being found in operation. To a lack of knowledge of how to grind the earth most efficiently more than to any other cause has been due the failure of American producers to meet the demand for earth suitable for use with edible oils. Fuller's earths grind very differently when subjected to the same grinding conditions, each earth having its especial peculiarities. Although the size of grain required varies with each oil and with the conditions of refining, the fact remains that in refining edible oil there is just as much necessity for a definite size of grain as in the refining of petroleum.

In the grinding of fuller's earth for refining petroleum, Alston, Max, Griffin, and roller mills are used. In one plant a bur mill had been used, but had been discarded at the time the plant was visited. The mills seen in plants operating on earths especially applicable to the refining of edible oils were bur mills, Sturtevant, Raymond, and beater mills. It was evident, in some instances at least, that the least suitable mill had been chosen for the particular earth being ground.

Fuller's earth for refining petroleum has to be bolted to definite sized grains to be marketed and it is placed on the market on the basis of 15 to 30 mesh, 30 to 60, 60 to 80, etc. The coarser sizes are in most demand, especially the 15 to 30 and 30 to 60 mesh sizes. It is difficult to find a market for the finer sizes, although for specific purposes certain special sizes, as 150 to 180 mesh, are sold. Moreover, about 15 per cent of the earth ordinarily becomes so fine in grinding that it is unmarketable and has to be thrown on the dump. The reduction

of this grinding loss is of the utmost importance to the mills producing earth for refining mineral oils.

For edible oils the idea has almost universally prevailed that the finer the earth was ground the better it would sell. As has been shown by Wesson^a and others, there is no question that the finer the grinding, the better the bleaching power; but, as will be shown later, other factors have to be considered, such as oil absorption and filter-press difficulties, which make it as necessary to keep down the proportion of fine material in earth prepared for edible oils as in the case of earth for mineral oils. This fact not having been recognized, American earths have usually been subjected to the same treatment the English earth received and, being so treated, have absorbed so much oil or have so clogged the filter presses as to be unmarketable. Though earth for edible oils should pass a 100-mesh sieve, it is equally important that the earth be not ground so fine that the very small particles fill the interstices between the larger grains, making filtration difficult or impossible, so that the oil retained by the earth can not be removed in the usual manner. Whether petroleum or edible oils are to be bleached, the same general principle applies to the grinding of the earth, namely, the elimination of too great a proportion of fine material. It is generally conceded by engineers that this can best be accomplished by the use of properly constructed roller mills, because such mills, if properly run, tend to crush rather than to grind the material.

Accordingly it seems that roller mills should give the most uniform product with the majority of fuller's earths. The use of rolls, however, may not always be necessary, for some earths when ground yield more fine material than others. English earth, for example, can evidently be ground in a bur mill so that it will pass a 120-mesh screen without giving any trouble in the filter presses. Most American earths, ground in the same way, although only to 100 mesh, give so large a proportion of practically impalpable powder that the product is absolutely useless for refining oil. Such material should be ground in rolls. If two rolls are used they preferably should have indented surfaces and should be run at the same speed. If a single roll passes over a stationary surface, much the same results are obtained. If fine material still gives difficulty, it will undoubtedly be necessary to set the mill so that only a part of the material passes through the bolters and part is returned to the rolls for regrinding. This will insure a much smaller proportion of fine material, even with rolls, than would be the case if the rolls are set so close that the material is crushed to size at a single operation.

^a Wesson, David, The bleaching of oils with fuller's earth: *Min. and Eng. World*, vol. 37, 1912, p. 667.

BOLTING THE GROUND PRODUCT.

After grinding, the fuller's earth is usually carried by means of screw conveyors to bolting machines. These bolting machines are similar to those used in the flour industry. By means of silk bolting cloth the material is divided into several sizes. In the case of earths used for refining petroleum the ground product is passed through several bolters, thus separating the earth into different grades, according to the size of the particles. In the case of earths used for refining edible oils, it is usually passed through a single 100-mesh sieve, although fuller's earth for refining edible oils has been put on the market by several plants without its being bolted.

RELATIVE PROPORTIONS OF PRODUCT ACCORDING TO SIZE.

After bolting, the product is placed in sacks and is then ready for shipment. The following figures show the relative amounts of each size into which 26,270,796 pounds of lump fuller's earth for refining petroleum was divided in one plant:

Product of a mill according to mesh.

Mesh.	Output.	
	Pounds.	Per cent.
15 to 30.....	3,601,260	13.7
30 to 60.....	10,607,760	40.4
60 to 80.....	1,576,260	6.0
60 up.....	3,129,906	11.9
100 up.....	1,106,622	4.2
50 to 180.....	1,380,078	5.25
170 up.....	24,624	.09
60 to 110.....	10,044	.04
Fine waste.....	4,834,242	18.40
Total.....	26,270,796	
Total bagged.....	21,436,554	81.6

LABORATORY METHOD OF DETERMINING FILTERING PROPERTIES.

It can not be determined with certainty from examination with sieves or bolting cloth whether or not very fine earth will act properly in the filter presses. The only laboratory method known to the bureau of determining the filtering properties of an earth is a comparative filtration test of the ground sample with earth that is known to filter readily. This comparative test can be made most easily with a Buchner or Hirsch funnel, which gives a very close approximation to the conditions in the mill. Although numerous mill tests are known in which earth was rejected on account of retaining too much oil or stopping up the filter presses, no previous experiments have

been carried on to determine the effect of extreme fineness in earths applied to edible oils. In order to get some light on the subject, the following experiments were performed:

Several samples of lump earth from different deposits were dried and ground. One portion of a sample was ground in a coffee mill so set that about half of the material would pass through a 100-mesh sieve, the residue being returned to the coffee mill and reground, and so on, until the whole had been reduced to 100-mesh. On examining this material with sieves it was found that a considerable portion of the product passed a 200-mesh sieve, but to determine this proportion with accuracy was not easy. A second portion of the same sample was ground in an agate mortar until the whole passed a 100-mesh sieve, and as was to be expected a larger portion passed a 200-mesh sieve than was the case in the first instance, but the difference could not be accurately determined. However, when the two portions were subjected to filtration tests it was at once apparent that there was a wide difference between them.

With the coffee-mill ground material filtration in a Buchner funnel was easy; the oil remaining was readily drawn out of the pores by suction and could have been further removed by blowing steam through the funnel, as is done in the filter press. With the mortar-ground earth the period of filtration was long and tedious and the remainder of the oil could not be satisfactorily extracted from the sample, which remained as thick, oily mud. Under the microscope it could be easily observed that the mortar-ground portion contained a much larger proportion of very fine material.

A number of tests were performed in a similar manner on different samples, the results of which are as follows:

Filtration tests of samples of fuller's earth.

Number of sample.	Where obtained.	Method of grinding.	Time of filtration.	Condition of residue.
			<i>Minutes.</i>	
1	Summerville, Tex.....	(In coffee mill.....	5.5	Mealy.
		(In agate mortar.....	10.5	Rather oily.
7	English earth.....	(In coffee mill.....	5.0	Quite dry.
		(In agate mortar.....	10.0	Fairly dry.
10	Pikes Peak, Ga.....	(In coffee mill.....	4.5	Quite dry.
		(In agate mortar.....	45.0	Very oily.
17	Midway, Fla.....	(In coffee mill.....	5.0	Quite dry.
		(In agate mortar.....	30.0	Very oily.
20	Klondike, Ark.....	(In coffee mill.....	12.0	Fairly dry.
		(In agate mortar.....	29.0	Very oily.

Samples of two of these earths as put on the market were tested and showed even poorer filtering qualities and retained a larger proportion of oil than did the mortar-ground material, which partly explains the difficulty experienced in disposing of such products.

USE OF FULLER'S EARTH.

As already stated, the original use of fuller's earth was for fulling cloth, but fulling has been almost entirely superseded by other methods of freeing cloth from grease. Fuller's earth suspended in water was rubbed into the cloth to absorb the grease, then the earth was washed out and the cloth dried. Disintegration in water is a rather essential property of fuller's earth used for this purpose and it is probably true that much of the material now considered the best for the purpose to which it is applied would be of comparatively little value for fulling cloth.

Attempts have been made to use fuller's earth as a filler for rubber goods, but without any marked success up to the present time. In the laboratory fuller's earth is used to detect the addition of certain coloring matters to butter, whisky, and artificial vinegar. In pharmacy it makes an excellent substitute for talcum powder on account of its absorptive powers, and certain earths are even claimed to have special virtue as a poultice for swellings, ulcers, and sores.

In the mills, which are sometimes dusty, no serious effects from dust upon the health of the operatives could be detected. It is even claimed that in one or two instances bad cases of catarrh had been actually cured by the absorptive character of the material. But dust in mills in such quantities as to be injurious to health is unnecessary and should not be tolerated.

Fuller's earth having a great absorptive power for basic colors has been used as a carrier for these colors in making cheap pigments for printing wall papers. Its chief use, as already pointed out, is for removing colors from fats, oils, and greases.

BLEACHING OF EDIBLE OILS WITH FULLER'S EARTH.

The method used in bleaching edible oils is essentially the same in general principle for all oils, but differs in detail. The temperature at which the bleaching takes place and the proportion of earth used vary not only with every oil, but also in the practice of the various refining plants as applied to similar oils. As cottonseed oil is by far the most important of those oils to which the process of refining is applied, it can best serve as an example.

Crude cottonseed oil is not affected by fuller's earth and it must first be subjected to the usual treatment with an alkali, which removes the fatty acids and at the same time converts the coloring matter into basic forms. Fuller's earth has no power to remove color from cottonseed oil until the crude oil has been treated with an alkali.

PROPORTIONS OF EARTH REQUIRED FOR DIFFERENT OILS.

Partly refined samples of different cottonseed oils require very different quantities of the same fuller's earth to remove the color. Accordingly, in the best practice, the oils that will require the least quantity of fuller's earth are selected by laboratory tests for bleaching.

With the finest qualities of cottonseed oil as little as $1\frac{1}{2}$ per cent of the best fuller's earth may give an effective bleach; with others as high as 6 per cent is required. Probably 3 per cent of fuller's earth is a fair average for bleaching cottonseed oil at the present time. The proportion of earth used also depends upon the temperature to which the oil is heated before treatment, although too great an increase in temperature may have a deleterious effect on the oil. In fact, it has been the practice of one plant to use in bleaching oils of special quality as much as 10 per cent of fuller's earth and a very low temperature.

MILL PRACTICE.

In ordinary practice a measured quantity of the dry cottonseed oil is placed in a large vat containing steam pipes and heated to near the boiling point of water (212° F.). The oil is then rapidly stirred by paddles and the necessary measured quantity of fuller's earth is added. Within one or two minutes the fuller's earth has been thoroughly mixed with the oil by the rapid agitation. The mixture is then run immediately to the filter presses and the fuller's earth filtered out. The quantity of oil for a single operation is so gaged that when all of the oil taken has passed through the filter press, the press itself is full of fuller's earth and is ready to be opened. Before the press is opened, as much oil as possible is blown out with steam and the oil is generally further removed by blowing air also through the press. In this latter operation certain Florida earths induce so rapid an oxidation of the oil that the material has been known to take fire in the press, destroying the filter cloths and endangering the plant. This difficulty, however, so far as known, is confined to one or two kinds of earth and does not ordinarily occur. It is customary, however, with all fuller's earths to remove the waste from the plant, either by washing it away with a stream of water or by carrying it to a near-by dump, because the plant is naturally always subject to dangers from spontaneous combustion of the mass.

EFFECT OF FINE GRINDING.

Rapidity of filtration and easy removal of the oil retained by the earth are not properties of a particular earth, as is generally supposed to be the case, but are conditions dependent upon the size of the particles of which the ground fuller's earth is composed. Although it

is true that fine grinding improves the bleaching properties of fuller's earth on account of the greater surface exposed, it is also true that a limit in fineness is easily reached beyond which the difficulties arising from slow filtration and from retention of oil become of greater moment than improvement of bleaching power. This point has been already brought out under the description of methods of grinding and bolting fuller's earth, but is of such great importance to the success of any plant producing this material that it can well be emphasized here.

The fuller's earth for refining edible oils should be reduced to the finest size that will work well in the filter presses, and no finer. This point can be determined and controlled with a fair degree of readiness by laboratory methods at the grinding plant.

REMOVAL OF TASTE AND ODOR FROM EDIBLE OIL TREATED WITH FULLER'S REVIVIFYING THE USED EARTH.

The color of the oil after treatment with fuller's earth is greatly reduced and its standard is immediately determined by means of color glasses of the Lovibond scale. Treatment with fuller's earth, however, besides reducing the color, also gives more or less taste and odor to the oil, which must be removed before the oil can be marketed.

This taste and odor is developed in oil by any fuller's earth so far found, but the extent of the action varies greatly with fuller's earth from different localities. English earth was long in special favor for refining edible oil because it imparts comparatively little taste and odor, but there are domestic earths that are equal to English earth in this respect, and just as good as regards bleaching qualities. However, the earths that bleach oil the best almost invariably give the greatest taste and odor to the oil, but this is not now nearly so serious an objection as formerly, as a method for removing taste and odor from edible oils is well known. With certain dark tallows and high-colored greases a larger proportion of fuller's earth must be used to remove the color. In any case, however, the general method of procedure is the same.

The method consists in blowing dry steam through the refined oil, which is heated in a so-called deodorizer to a temperature above the boiling point of water. The best results are obtained when the oil is under reduced pressure. The deodorizer consists essentially of a large container fitted with pipes through which high-pressure steam can be passed to heat the oil to the desired temperature, and an additional steam pipe at the bottom with perforations through which superheated steam can be blown. Often the deodorizer has a goose-neck exit which serves as a kind of trap. The steam in passing off

carries with it the material giving the undesirable taste and odor to the oil. There is little difference in the treatment whatever variety of fuller's earth is used, but oils treated with earths which give high taste and odor naturally require somewhat longer contact with steam.

In the treatment of lard and lard oil it is seldom if ever necessary to use more than 1 per cent of fuller's earth and generally the lard is not deodorized afterwards.

REVIVIFYING THE USED EARTH.

Practically all of the fuller's earth used in bleaching edible oils is now thrown on the dump and carries with it an amount of oil varying from 10 to 20 per cent of the weight of the discarded material. As some 25,000 tons of spent fuller's earth was so discarded last year it can be readily estimated that between 2,500 and 5,000 tons of valuable oil was thrown away as well.

The methods of revivifying fuller's earth used in refining mineral oil are not applicable to earth used in refining edible oils, and accordingly in actual practice on such oils fuller's earth is now used but once. To revivify fuller's earth residues from edible oils is, however, an easy matter in the laboratory, and apparently requires only the solution of mechanical detail to make it practicable in the factory.

The oil can be readily extracted from fuller's earth with naphtha, benzol, carbon tetrachloride, or other oil solvent, and under these conditions the coloring matter is left behind with the earth. If this treatment is followed by a treatment with alcohol, the major part of the coloring matter is also removed from the earth, but the earth does not entirely regain its former bleaching power. This is due to the fact that certain basic colors adhere very strongly to the earth, even in the presence of alcohol. Accordingly, if to the alcohol, mixed with a certain proportion of an oil solvent like benzol, a small quantity of acid is added, the basic colors are converted to a salt of the acid, and in this form are then readily removed by the solvent. The whole process can be carried on at one operation by mixing the solvent for the oil, the alcohol, and the acid in one solution. By using such a solution the oil is removed from the earth, together with all of the original coloring matter, and the earth bleaches as effectively as it did in the first instance. This process has been tried out by the author many times with the same sample of fuller's earth, the bleaching power of which was not diminished in the slightest after many trials.

LABORATORY METHODS FOR TESTING FULLER'S EARTH FOR USE WITH EDIBLE OILS.**BLEACHING TEST OF FULLER'S EARTH.**

In determining the decolorizing power of fuller's earth for use for edible oils a quantity of oil should first be selected which is sufficient for all of the tests to be made, as different samples of oils are bleached very differently by the same earth. With cottonseed oil a definite quantity of oil is weighed or measured, placed in a beaker, and heated (preferably in a water bath) to 100° C. The sample of fuller's earth, unless already ground, is first carefully pulverized, preferably in a coffee mill, to pass a 100-mesh sieve. A portion of the pulverized sample, ordinarily 5 per cent of the quantity of oil taken, is weighed and stirred into the hot oil. The stirring is continued for three minutes. The mixture is immediately filtered into a sample bottle, such as is universally used in testing for oil color. If at the same time it is desired to determine the quality of the earth as regards its action in the filter presses, its filtration should take place on a Buchner funnel, using suction. If the question of filtration is not of moment, it is usually simpler to filter through an ordinary steam-jacketed funnel, using filter paper. A portion of the same sample of oil is then treated with a sample of standard fuller's earth, for which purpose the English earth is universally used, and the colors of the two oils obtained are compared in a colorimeter by means of Lovibond color glasses. The only glasses required are the red and the yellow series.

RESULTS OF BLEACHING TESTS OF FULLER'S EARTH.

In order to determine the bleaching power of American fuller's earth as well as can be accomplished in the laboratory, the following tests were made. The oil, a selected "prime summer yellow," was treated with 5 per cent of its weight of fuller's earth at 100° C. for three minutes and filtered. Results are given in terms of the Lovibond scale, the figures being proportional to the depth of color, so that the smaller figures indicate better bleaching qualities than the larger figures. No attempt was made to estimate the degree of taste and odor imparted to the oil as no basis of comparison could be developed. It may be stated, however, that in general the better the bleach, the stronger the taste and odor that was imparted to the oil. It should be remembered that this question of taste and odor given to cottonseed oil is now of comparatively minor importance as they can generally be removed in the deodorizer. The results obtained were as follows:

Bleaching tests of fuller's earth.

Number of sample.	Source of earth.	Color readings, Lovibond scale.		Remarks.
		Yellow.	Red.	
1	Summerville, Tex.	16	1.6	Mill ground.
2	Vacaville, Cal.	34	3.4	Coffee-mill ground to 100-mesh.
3	Unknown, Cal.	35	5.0	Do.
4	do.....	35	4.8	Do.
5	do.....	22	2.2	Do.
6	do.....	35	4.2	Do.
7	England	20	2.0	Do.
8	Sumter, S. C.	16	1.6	Do.
9	Moultrie, Ga.	14	1.4	Do.
10	Pikes Peak, Ga.	14	1.4	Do.
11	do.....	12	1.2	Mill ground.
12	Fitzpatrick, Ga.	14	1.4	Coffee-mill ground.
13	Unknown, Ga.	14	1.4	Do.
14	Ellenton, Fla.	22	2.2	Do.
15	do.....	20	2.0	Do.
16	Attapulgus, Ga.	14	1.4	Do.
17	Midway, Fla.	16	1.6	Mill ground.
18	England (I. X. L. brand).	20	2.0	As imported.
19	Fairplay, Ark.	16	1.6	Mill ground.
20	Klondike, Ark.	20	2.0	Coffee-mill ground.
21	Lancaster, Mass.	35	4.0	Bolted through 100-mesh.
22	Fort Payne, Ala.	18	1.8	Coffee-mill ground.
23	Andalusia, Ala.	28	2.0	Do.
X	Oil used.	35	6.2	

In considering these figures it should be remembered that these tests were made with cottonseed oil only and do not necessarily bear any relation to the bleaching effect on mineral oils. Indeed as regards edible oils several of these clays should not be classified as fuller's earths at all.

Experiments on the comparative bleaching power for petroleum products were not undertaken, as domestic fuller's earth only is used for this purpose in America. Years of application have apparently already firmly fixed market standards for the fuller's earths used in this industry.

EFFECT OF LIGHT ON BLEACHED OILS.

It has been long known that oils bleached by fuller's earths are further bleached by exposure to light. Accordingly the bleached oils from the above tests were exposed for four weeks to the diffused sunlight of a well-lighted room and readings again taken. Little beyond the mere fact of further decolorization can be deduced from the results, but they would seem to indicate that in certain earths the subsequent bleaching by light is accelerated. This deduction is, however, by no means sure; nor, if proven, does it have any bearing on present commercial practice. The following results may, however, prove of interest.

Results of exposure of bleached oils to light.

Number of sample.	Color readings, Lovibond scale.		Number of sample.	Color readings, Lovibond scale.	
	Yellow.	Red.		Yellow.	Red.
X ^a	35	5.2	11.....	10	1.0
1.....	11	1.1	12.....	13	1.3
2.....	30	3.0	13.....	10	1.0
3.....	35	4.6	14.....	12	1.2
4.....	35	4.3	15.....	20	2.0
5.....	20	2.0	16.....	11	1.1
6.....	35	4.0	17.....	11	1.1
7.....	15	1.5	18.....	16	1.6
8.....	11	1.1	19.....	13	1.3
9.....	15	1.5	20.....	12	1.2
10.....	9	0.9			

^a Unbleached.

METHOD OF MAKING FILTRATION AND OIL-ABSORPTION TESTS.

The rate of filtration and the character of the residue may be readily determined for any sample of fuller's earth by use of the Buchner funnel, as previously stated. The rate of filtration of an oil through the prepared earth as compared with the rate of filtration of some of the same oil through a sample of fuller's earth known to work well in the filter press, and the character of the residue, will give a good idea of actual working conditions in the mill. It should be especially remembered, however, that this test applied to a laboratory ground sample means nothing, and is valuable only in determining whether or not a sample from a particular mill will give results in the filter press comparable to those obtained from other mill products known to work well in the press. The method will prove of especial value in the technical control of a grinding plant, for the mill chemist can determine in the laboratory whether or not the mill is turning out a regular product and how this product will probably act in the filter press.

MILL TESTS OF FULLER'S EARTH.

Although laboratory methods correctly applied may give an excellent idea of the quality of any sample of fuller's earth, no refiner will introduce a particular earth into his practice without more or less extensive mill tests of the material. Before submitting a sample of ground earth for such mill tests the producer should assure himself by laboratory tests not only that his material bleaches well, but also that he is ready to furnish a regular product of at least 100-mesh fineness and so ground that it does not contain so much extremely fine material that it will not work smoothly in the filter presses or will absorb too much oil.

For a fair comparison the refiner should take the precaution to use equal weights, not equal measures, of the two earths he may be comparing as to bleaching quality. He should make his bleaching tests on the same oil stock and should see that the test does not fail through any tendency on the part of his workmen to attribute any lack of success wholly to the new earth when there may be other possible factors that could be easily overcome with proper care and forethought.

In addition to the laboratory tests described above much information was obtained as to actual mill experience, both in the country and abroad. While the actual practice of mills in regard to the use of specific brands of fuller's earth can not be given in this bulletin, it may be stated here that one of the largest American refining companies now uses no foreign earth, but purchases annually some 4,000 tons of American earth, which is used chiefly in bleaching cottonseed oil. Also an increasing demand for American fuller's earths for foreign consumption is manifest.

BLEACHING OF MINERAL OILS WITH FULLER'S EARTH.

Fuller's earths that are good bleaching agents for edible oils are not necessarily, and in fact seldom are, the best bleaching agents for mineral oils. English earth, for example, is seldom used for bleaching such oils in this country, and on the other hand the Florida earths, which are chiefly used for bleaching petroleum, have little application in the edible-oil industry.

In the milling of these earths, as already pointed out, they are carefully screened, so that the size of the particles lies within fairly definite limits, the grades most used in practice being 15 to 30, 30 to 60, and 60 to 80 mesh. The finer material, most of which does not find a ready market, is, however, sometimes used for special purposes, such as the decolorization of vaseline. Very little fuller's earth is used in decolorizing kerosene, but it is quite customary to treat kerosene with a small proportion of fuller's earth to remove the "floc" which causes turbidity on cooling. The amount of earth so used, however, is small, and is used with oils of very low viscosity. Very fine grades of earth are used, and the oil is run through a filter press to remove the earth. In filtering mineral oils through fuller's earth the oil may or may not be heated before filtration. Paraffin, petrolatum, etc., naturally are heated to diminish their viscosity and will then pass readily through earth of comparatively fine mesh, while many of the spindle and lubricating oils are simply filtered cold through earth of coarser mesh. The practice varies greatly in this respect at various works and is determined largely by local conditions and the character of the product desired.

The fuller's earth of the grade chosen is placed in a tall, cylindrical percolator with closed, rounded ends. Through this column of fuller's earth, some 15 feet in height, the oil is forced under sufficient pressure to allow it to run freely from the bottom. The filtered oil is run into different storage tanks, according to color. The filtering is continued until the earth no longer bleaches properly. The percolator carries from 18 to 25 tons to a charge. The quantity of oil decolorized by one charge of fuller's earth varies greatly, both with the oil used and the degree of color desired, and no figures of value can be given. Seven hundred barrels of oil to 25 tons of earth are by no means a maximum; nor are 150 barrels of oil to 25 tons of earth a minimum for oils difficult to decolorize. The size of grain of the earth selected for use in a refinery varies with the viscosity of the oil, the temperature at which filtration takes place, and the practice of the particular plant with reference to the results desired.

When the fuller's earth used has become useless for further decolorization the percolator is blown out with air to remove as much as possible of the oil remaining between the particles, and the residue is washed with naphtha to recover the oil still adhering to the grains. Following this extraction the percolator is blown out with steam to remove the residual naphtha. The naphtha is practically all recovered by distillation and the dissolved oil is re-treated in the next batch.

METHOD OF REVIVIFYING THE USED EARTH.

The hot fuller's earth drops from the percolator to a belt conveyor, and is carried to a rotary kiln, similar to the smaller sizes used in making Portland cement. The earth, in passing through the kiln, is ignited at a low, red heat, which treatment revivifies the earth so that it can be used again. Indeed, even the fresh earth is heated in the rotary kiln before the first filtration, in order to remove free and combined water, of which it contains approximately 15 per cent. From the kiln the revivified earth passes through a cooling apparatus. It is then carried by a belt conveyor back to bins, from which it is conducted to percolators, to be used again. Ordinarily fuller's earth may be used from 10 to 16 times, gradually losing its decolorizing power. The last filtrations are made either upon oils that require less earth to decolorize them or upon oils that do not need to be bleached so completely.

In the revivifying of fuller's earth in the rotary the rubbing naturally causes more or less abrasion of the particles. Much of the fine material so produced is carried up the stack or into the dust chambers by the draft. The loss from this source during each operation varies greatly, but may be roughly estimated as approaching 3 per cent of the material treated. Care has to be exercised not to heat the earth

too highly or incipient fusion may take place. Recent investigations indicate that the danger of fusion may be greatly diminished by a previous treatment, details of which have not been published, and that when so treated the number of times the earth may be revived and used again is greatly increased.

EFFECT OF PERCOLATION ON VISCOSITY AND SPECIFIC GRAVITY OF PRODUCT.

It is particularly interesting to note, as has already been shown by others,^a that the percolator not only separates the oil into fractions of different color, the first being bleached much more completely than the fractions which pass through the earth during the later periods, but also tends to separate oil into fractions of different viscosity, the first fractions of oil being much less viscous than the final fractions. With the change in viscosity other changes also naturally take place. For example, the specific gravity and flash point of oil from the first operations are notably less than those of oil from the last fractions, and the cold tests also give higher results. The following figures obtained from aliquot portions of 5 barrels each in an actual run of 100 barrels of spindle oil filtered through 25 tons of earth are instructive:

Results of viscosity test of spindle oil.

Barrels.	Viscosity. ^b	Temperature.
		° F.
1st to 5th.....	187	31.5
5th to 10th.....	220	29.7
10th to 15th.....	242	28.6
15th to 20th.....	253	28.2
20th to 25th.....	260	27.9
25th to 30th.....	265	27.6
30th to 35th.....	266	27.5
35th to 40th.....	268	27.3
40th to 45th.....	271	27.3
45th to 50th.....	273	27.2
50th to 55th.....	274	27.2
55th to 60th.....	274	27.1
60th to 65th.....	275	27.1
65th to 70th.....	275	27.1
70th to 75th.....	277	27.0
75th to 80th.....	277	27.0
80th to 85th.....	278	27.0
85th to 90th.....	278	27.0
90th to 100th.....	278	27.0
Average of first 25.....	224	29.6
Average of first 50.....	246	28.4
Average of first 75.....	258	28.0
Average of first 100.....	259	27.8

^a Day, D. T., A suggestion as to the origin of Pennsylvania petroleum; Proc. Am. Phil. Soc., vol. 36, 1897, pp. 112-115; Gilpin, J. E., and Cram, M. P., The fractionation of crude petroleum by capillary diffusion: Am. Chem. Jour., vol. 40, 1908, p. 495; Gilpin, J. E., and Bransky, O. E., The diffusion of crude petroleum through fuller's earth: Am. Chem. Jour., vol. 44, 1910, p. 251; Herr, V. F., Filtration of Baku petroleum through fuller's earth: Petroleum, vol. 4, 1909, p. 1284.

^b The viscosity was determined at 70° F. with a Seybolt viscosimeter.

It will thus be seen that by means of the fuller's-earth filtration alone mineral oils may be separated into fractions of distinctly different physical properties. This method is incidentally used to a limited extent to obtain oils of desired properties.

METHOD OF TESTING FULLER'S EARTH FOR ITS DECOLORIZING POWER ON PETROLEUM.

The method of testing fuller's earth for its bleaching power on petroleum oils differs from that used in testing earth used for edible oils. Instead of taking a fixed quantity of earth and measuring its decolorizing effect on a fixed quantity of a selected oil, the method depends upon the quantity of a particular oil that a fixed quantity of earth will bleach to a definite standard.

The earth, which has been screened to the size to be tested, is placed in an ordinary percolator filled to a definite volume; or the test may be made with a definite weight of earth. A volume test, however, is generally preferred, as it represents, between the different earths, more nearly the bleaching power which would result from a full charge in one of the regular decolorizers. An appropriate oil is selected, and a definite quantity is allowed to percolate through the earth. Samples are taken from time to time, and the color is determined by comparison with Lovibond color glasses. An equal quantity of the same oil is then filtered through the same volume of a standard fuller's earth and the quantity of oil bleached is compared with that obtained with the first sample. The result naturally is simply comparative, as, indeed, is the case with all tests of fuller's earth, whether for use on animal or vegetable oil, for not only do earths vary in bleaching powers, but different oils require different quantities of the same earth to accomplish like decolorization.

In practice, the method described is used more often to determine the actual working conditions of the mill than to determine the quality of a fuller's earth, since petroleum refineries use fuller's earth from one or two deposits which yield earth that varies but little in quality.

By percolating the oil through a definite volume of earth (ordinarily 500 c. c.), as indicated above, and determining the decolorizing effect upon the oil, it is easy to estimate the number of barrels of oil that will be decolorized by the charge placed in the large percolator used in the works. From a test of this kind with a sample of oil submitted to the laboratory the number of barrels of oil of various grades of color, viscosity, etc., that would be obtained in the works practice from a shipment of the same kind of oil may be quite accurately predicted.

EFFECT OF HEAT ON FULLER'S EARTH.

Although the removal of water of composition from fuller's earth for bleaching mineral oils is almost universally practiced, nevertheless there is a general belief that heating above the boiling point of water in drying fuller's earth to be used for edible oils will destroy its bleaching power. This belief is sometimes but not always correct, as the following tests indicate:

Results of heating test on earths for refining edible oil.

Number of sample.	Source of sample.	Loss of water.	Color reading, Lovibond scale.			
			Before heating.		After heating to red heat.	
			Yellow.	Red.	Yellow.	Red.
11	Pikes Peak, Ga.....	<i>Per cent.</i> 12	12	1.2	12	1.2
18	England (I X L brand).....	17.9	20	2.0	24	2.4
20	Klondike, Ark.....	15.6	20	2.0	20	2.0

In these tests 6 grams of air-dry earth previously dried at a temperature not exceeding 100° C. is compared with the residue from 6 grams of the same earth heated in a platinum crucible to a red heat. It will be noted that the bleaching power of the English earth is seriously reduced by driving off the combined water, but that some other earths do not appear to be affected adversely.

DETERMINATION OF SPECIFIC VOLUME OF FULLER'S EARTH.

The volume occupied by a definite weight of fuller's earth is of importance as affecting the number of times a filter press must be opened for a given quantity of earth and also in determining the size of measure to use in adding the earth to the oil. The true specific gravities of the various fuller's earths do not differ nearly so much as do the apparent specific gravities, owing to the different ways in which ground fuller's earth from different localities tends to pack. Accordingly, the space occupied by wet material need not necessarily be proportional to that occupied by the material when dry.

Most of the southeastern fuller's earths are extremely light and require more sacks per ton than do the English and western fuller's earths. Also they generally take up more space in the filter presses for a given weight. It is difficult to determine in the laboratory with certainty the weight per cubic foot of material as it will appear in the market, because the space occupied depends greatly upon settling, tamping, etc. The following figures will, however, give at least a comparative idea of the specific volumes of the various fuller's earths considered in this paper.

The difference in weight of equal volumes of different earths was determined under as nearly identical conditions as possible. The method consisted of taking a small glass flask, weighing it, and filling it with the finely ground earth, tapping the flask at the same time on the table to settle the material, until it would hold no more. The weight of the contents was then ascertained. It should be remembered that the results are comparative rather than absolute. They are, however, much more valuable than exact determinations of specific gravity, as the true specific gravity gives little indication of the space actually occupied by the ground material. The results obtained were as follows:

Weight per cubic foot of different fuller's earths.

Number of sample.	Source of earth.	Weight per cubic foot.	Number of sample.	Source of earth.	Weight per cubic foot.
		<i>Pounds.</i>			<i>Pounds.</i>
1	Summerville, Tex.....	61	11	Pikes Peak, Ga.....	40
2	Vacaville, Cal.....	51	12	Fitzpatrick, Ga.....	42
3	California (locality unknown).	68	13	Georgia (locality unknown)	64
4	do.....	58	14	Ellenton, Fla.....	36
5	do.....		15	do.....	34
6	do.....	75	16	Attapulugus, Ga.....	35
7	England.....	68	17	Midway, Fla.....	30
8	Sumter, S. C.....	36	18	England (I X L brand)....	75
9	Moultrie, Ga.....	33	19	Fairplay, Ark.....	79
10	Pikes Peak, Ga.....	35	20	Klondike, Ark.....	75
			21	Lancaster, Mass.....	78

SPECIAL TREATMENTS OF FULLER'S EARTH.

Many attempts have been made to increase the bleaching power of fuller's earth by various chemical treatments.^a It seems probable that treatment with acid by removing any calcium carbonate present tends to have a slight beneficial effect. Improvement in bleaching power brought about by treatment with acids has, however, never been found commercially practicable. Alkalies invariably diminish and in some cases almost entirely destroy the bleaching power of fuller's earth. One company claims to be using a special electrical treatment which is said to increase the bleaching power, but no details have been furnished the bureau.

Through the courtesy of Dr. Harry McCormack two samples of fuller's earth sent from the Bureau of Mines were treated with ionized air or air which had been subjected to the influence of a strong electrical discharge. In both instances a slight increase of bleaching power was observed, but more extensive experiments will be necessary to determine whether or not the idea may be applied on a commercial scale.

^a Porter, J. T., Properties and tests of fuller's earth: U. S. Geol. Survey Bull. 315, 1906, p. 272.

EFFECT OF "ACIDITY" ON PROPERTIES OF FULLER'S EARTH.

Most fuller's earths, as already pointed out, give a distinct acid reaction with litmus or phenolphthalein. The degree of this "acidity," which is in nowise an indication that any acid is present, can be readily determined by stirring the finely ground earth in water, adding phenolphthalein, and titrating with an alkali until the solution turns pink. This power to adsorb bases is so marked in certain samples of fuller's earth and has so wide a range that it was deemed advisable to make "acidity" tests of the various samples under investigation. Although it should be noted that the bleaching power is not proportional to the degree of "acidity," it is, however, a striking fact that those earths which show by this test the highest adsorptive power for bases are also those which have the strongest bleaching action. The samples that had little or no bleaching power did not show this property. Indeed, one or two such samples gave an alkaline reaction, indicating that they came from the so-called alkali lands. Possibly the bleaching properties which they may originally have had have been destroyed by the natural alkalinity of the percolating waters.

Different samples of fuller's earth were tested for degree of "acidity" by the following method:

Two grams of earth in suspension in 100 c. c. of water were titrated with a standard $\frac{N}{10}$ solution of sodium hydroxide, phenolphthalein being used as indicator. The results are tabulated below.

Results of "acidity" tests of fuller's earth.

Number of sample.	Source of earth.	$\frac{N}{10}$ NaOH for 100 grams of earth.	Number of sample.	Source of earth.	$\frac{N}{10}$ NaOH for 100 grams of earth.
		<i>C. c.</i>			<i>C. c.</i>
1	Summerville, Tex.....	120	11	Pikes Peak, Ga.....	230
2	Vacaville, Cal.....	0	12	Fitzpatrick, Ga.....	20
3	California (locality unknown).....	0	13	Georgia (locality unknown).....	80
4	do.....	0	14	Ellentown, Fla.....	30
5	do.....	90	15	do.....	25
6	do.....	0	16	Attapulugus, Ga.....	20
7	England.....	15	17	Midway, Fla.....	20
8	Sumter, S. C.....	85	18	England (I. X. L. brand).....	60
9	Moultrie, Ga.....	35	19	Fairplay, Ark.....	125
10	Pikes Peak, Ga.....	175	20	Klondike, Ark.....	65

ADSORPTION OF ANILINE DYES BY FULLER'S EARTH.

Fuller's earths that give an "acid" reaction also adsorb basic colors from water solutions as well as from oil solutions. Accordingly, if solutions of such basic aniline colors as malachite green, methylene blue, fuchsine, and other similar dyes are treated with fuller's earth

in excess, the fuller's earth will completely remove these aniline colors. The water as it issues from the percolator is quite colorless, whereas the fuller's earth itself takes on the hue of the particular dye used, forming pigments that may find more extensive application than at present. Acid colors, however, like magenta and eosine are not adsorbed.

In order that these pigments may have value, it is of course necessary that the color of the fuller's earth itself shall not modify seriously the color adsorbed by it. Certain finely ground and nearly white clays of high adsorptive power have been imported from Germany to be used in the production of clay pigments as a basis for color printing on wall papers. While these samples of imported clay can not be positively identified, certain brands strongly resemble samples from one or two American deposits of fuller's earth, and there is every reason to believe that the material was exported and after specially fine grinding was reimported into this country. Material that is to be used for the production of such pigments can not be too finely ground. Naturally pigments made in this way from aniline colors are far from permanent when exposed to light, but when fresh they are as bright and brilliant as any colors produced and they may be given a temporary sheen similar to that of satin by subjecting them to ammonia fumes.

This adsorptive power of certain fuller's earths is as definite for these basic colors as it is for alkalis, such as sodium and calcium hydroxide, and with care fuller's earth can be titrated with a solution of one of these colors almost as readily as it can be titrated with an alkali. The only difficulty is in determining the end point. The sample of fuller's earth giving the highest test for "acidity" among those listed on page 30 will remove over 3 per cent of its own weight of fuchsine from solution in water and leave the water as colorless as before the dye was adsorbed.

The adsorption of aniline dyes by various forms of clay is by no means new. Ashley^a gives a method for determining the adsorptive power of clays for malachite green which has been quite extensively used in determining the so-called colloid content of clays. In determining the adsorptive power of fuller's earth it is much simpler to titrate the mixture of earth and water with a solution of sodium hydroxide, for the alkali adsorption is apparently proportional to the adsorptive power for basic colors. Although azo colors are removed from solution in oil by fuller's earth giving a high "acid" reaction, the adsorbed color is always converted into the shade that it would assume if it were really converted into an acid salt of the color.

^aAshley, H. E., The colloid matter of clay and its measurement: U. S. Geol. Survey Bull. 388, 1909, pp. 46, 47.

The presence of these colors in butter or other artificially colored products can be detected and identified in this manner.

It is quite possible that fuller's earth colored by adsorbed aniline dyes may yet find more extensive application in the industries. Already some 200 to 300 tons are used annually in the woolen industry for removing excess of coloring matter from the goods after dyeing.

THEORY OF BLEACHING ACTION.

For many years the cause of the bleaching action of fuller's earth was not understood. Many explanations were offered, such as chemical changes in the color brought about by the fuller's earth, the entangling and retaining of the coloring matter in the pores of the fuller's earth, and other explanations equally unsatisfactory. The bleaching action has, however, been shown to be entirely physical in its nature and due to the phenomenon known as adsorption, which in its application to fine mineral particles of clays has been fully treated by Cameron,^a and by Ashley.^b

The fact that fuller's earth appears to carry an unusually large proportion of colloids of high adsorptive power and that its bleaching action was due to this fact was first brought out by Parsons in a paper^c read before the Northeastern Section of the American Chemical Society.

The theory was independently advanced by Porter^d also. That the action is physical can readily be shown from the fact that the color may be added to or taken from the fuller's earth at will by using proper solvents.

COSTS OF PRODUCTION OF FULLER'S EARTH.

The costs of mining, milling, and marketing fuller's earth vary so greatly with local conditions that no figures of real value upon which a prospective producer could base an estimate can be given. The distance from railroads and markets, the quality of the earth, the extent of the deposit, the depth of overburden, the removal of surface and ground waters, wages, and fuel supply must all be given careful consideration. Possibly the most important factor, however, is that of overhead charges, which must be borne whether 1,000 tons or 10,000 tons are produced.

The large producer of fuller's earth will always have a great advantage over the small producer in mining and milling the material and

^a Cameron, F. K., and Bell, J. M., Mineral constituents of the soil solution: Bureau of Soils Bull. 30, 1905, p. 42.

^b Ashley, H. E., The colloid matter of clay and its measurement: U. S. Geol. Survey Bull. 388, 1909, pp. 31-51.

^c Parsons, C. L., Fuller's earth and its application to the bleaching of oils: Jour. Am. Chem. Soc., November, 1906, vol. 29 (1907), p. 598.

^d Porter, J. T., Properties and tests of fuller's earth: U. S. Geol. Survey Bull. 315, 1906, pp. 276-289.

in marketing his product. A deposit should not be exploited until the factors of cost and the difficulty of introducing an unknown product into the market have been carefully considered. The large producer can use steam shovels for removing both the overburden and the fuller's earth, and where he moves thousands of tons the cost of removal per ton is greatly reduced, as is always the case in mining operations. Also the cost of supervision, of technical control, selling costs, etc., must of necessity be less per ton of product when the output is large. Many of the small companies have already failed through lack of appreciation of the high unit cost of small production and lack of proper technical control.

The cost of production may be divided into stripping, mining, crushing, drying, milling, bagging, and shipping costs. Of these items the cost of drying is almost universally the highest and the figures reported to the bureau are not easy to explain. It is undoubtedly true that drying fuller's earth is in practice a more expensive operation than the drying of most other materials.

Besides the items named, the charges regularly made in any business to cover depreciation of plant, amortization, etc., should of course always be taken into consideration.

SUMMARY OF PRECAUTIONS TO BE OBSERVED IN PREPARING FULLER'S EARTH FOR BLEACHING EDIBLE OILS.

A summary of the more important precautions that ought to be observed by the producer in preparing fuller's earth for use in the preparation of edible oil is here given.

(1) The fuller's earth should bleach as well as or better than the standard English earth. This bleaching property is inherent in each particular deposit of fuller's earth and can be destroyed by treatment with alkali, but no commercial process has been developed that can increase this bleaching power, except to a very small degree. The bleaching power can be determined readily and accurately in the laboratory by comparison on the same oil with a fuller's earth of known quality. The degree of the bleaching power is by far the most important property of a fuller's earth and really determines whether or not a particular clay should be so designated. Unless a fuller's earth bleaches as well as or better than the English earth does, it has little chance for finding a market in the edible oil industry.

(2) The earth should act well in the filter press. This property of a ground earth is dependent upon the method of grinding used. The particles of the ground earth should be as fine as possible, but not so fine that they will cause the material to clog the filters. The material must in any case be fine enough to pass a 100-mesh sieve, but the limit of fineness can be determined only by actual mill tests in the

filter press or approximately by comparative laboratory tests. In any American mill preparing fuller's earth for the market, filtration tests should be made regularly in order to determine the character of the product, and any material that does not act well in the filter press should not be put on the market. The earth should be as finely ground as will still permit free filtration, for the finer the article is ground the stronger is its bleaching power. In order to produce a marketable product, sufficiently fine, but without too large a content of extremely fine material, a mill of the roller type is to be preferred.

(3) The earth should not absorb too much oil nor retain too much in the filter. As edible oils are costly, this property is of great importance. It really is dependent upon the same physical characteristics as is ease of filtration. The size of the ground particles being left out of consideration, it is probable that one fuller's earth tends to absorb about the same amount of oil as another. The finer the particles are, the larger will be the proportion of oil retained in the filter press.

(4) The earth must not cause the oil to oxidize so rapidly when air is blown through the filter press that the mass will catch fire. This property is not sufficiently marked in earth from most American deposits to cause any difficulty. Only one type of fuller's earth is now reported to possess this property. As this danger applies to oxidizable oils alone it is not to be feared in any case in petroleum refineries.

(5) The earth should not give to the oil a permanent taste or odor which can not be removed in the deodorizer. A few types of fuller's earth contain soluble matter which can be easily washed out with water; most deposits do not. If sufficient soluble alum or iron sulphate is present it is fatal to the usefulness of the material. This difficulty, however, occurs in only one or two known instances. Ordinarily the taste and odor given to edible oils by fuller's earth can be removed by means of steam under proper conditions of temperature and pressure. However, other things being equal, the earth giving the least degree of taste and color, even if these blemishes are removable, is to be preferred. The earth itself can not be treated so as to destroy this property without destroying the bleaching power also.

PUBLICATIONS ON METHODS OF MINING AND MINERAL TECHNOLOGY.

The following Bureau of Mines publications may be obtained free by applying to the Director, Bureau of Mines, Washington, D. C.:

BULLETIN 3. The coke industry of the United States as related to the foundry, by Richard Moldenke. 1910. 32 pp.

BULLETIN 10. The use of permissible explosives, by J. J. Rutledge and Clarence Hall. 1912. 34 pp., 5 pls., 4 figs.

BULLETIN 12. Apparatus and methods for the sampling and analysis of furnace gases, by J. C. W. Frazer and E. J. Hoffman. 1911. 22 pp., 6 figs.

BULLETIN 16. The uses of peat for fuel and other purposes, by C. A. Davis. 1911. 214 pp., 1 pl., 1 fig.

BULLETIN 17. A primer on explosives for coal miners, by C. E. Munroe and Clarence Hall. 61 pp., 10 pls., 12 figs. Reprint of United States Geological Survey Bulletin 423.

BULLETIN 19. Physical and chemical properties of the petroleum of the San Joaquin Valley, Cal., by I. C. Allen and W. A. Jacobs, with a chapter on analyses of natural gas from the southern California oil fields, by G. A. Burrell. 1911. 60 pp., 2 pls., 10 figs.

BULLETIN 22. Analyses of coals in the United States, with descriptions of mine and field samples collected between July 1, 1904, and June 30, 1910, by N. W. Lord, with chapters by J. A. Holmes, F. M. Stanton, A. C. Fieldner, and Samuel Sanford. 1913. 1200 pp., 1 fig.

BULLETIN 44. First national mine-safety demonstration, Pittsburgh, Pa., October 30 and 31, 1911, by H. M. Wilson and A. H. Fay, with a chapter on the explosion at the experimental mine by G. S. Rice. 1912. 75 pp., 7 pls., 4 figs.

BULLETIN 47. Notes on mineral wastes, by C. L. Parsons. 1912. 44 pp.

BULLETIN 45. Sand available for filling mine workings in the Northern Anthracite Basin of Pennsylvania, by N. H. Darton. 1913. 33 pp., 8 pls., 5 figs.

BULLETIN 48. The selection of explosives used in engineering and mining operations, by Clarence Hall and S. P. Howell. 1913. 50 pp., 3 pls., 7 figs.

BULLETIN 53. Mining and treatment of feldspar and kaolin in the southern Appalachian region, by A. S. Watts. 1913. 171 pp., 16 pls., 12 figs.

BULLETIN 62. National mine-rescue and first-aid conference, Pittsburgh, Pa., September 23-26, 1912, by H. M. Wilson. 1913. 74 pp.

BULLETIN 64. The titaniferous iron ores of the United States, their composition and economic value, by J. T. Singewald, jr. 1913. 145 pp., 16 pls., 3 figs.

BULLETIN 65. Oil and gas wells through workable coal beds; papers and discussions, by G. S. Rice, O. P. Hood, and others. 1913. 101 pp., 1 pl., 11 figs.

BULLETIN 71. Uranium, vanadium, and radium, a preliminary report, by R. B. Moore and K. L. Kithil. 1913.

TECHNICAL PAPER 1. The sampling of coal in the mine, by J. A. Holmes. 1911. 18 pp., 1 fig.

TECHNICAL PAPER 3. Specifications for the purchase of fuel oil for the Government, with directions for sampling oil and natural gas, by I. C. Allen. 1911. 13 pp.

TECHNICAL PAPER 8. Methods of analyzing coal and coke, by F. M. Stanton and A. C. Fieldner. 1913. 42 pp., 12 figs.

TECHNICAL PAPER 11. The use of mice and birds for detecting carbon monoxide after mine fires and explosions, by G. A. Burrell. 1912. 15 pp.

TECHNICAL PAPER 13. Gas analysis as an aid in fighting mine fires, by G. A. Burrell and F. M. Seibert. 1912. 16 pp., 1 fig.

TECHNICAL PAPER 14. Apparatus for gas analysis laboratories at coal mines, by G. A. Burrell and F. M. Seibert. 1913. 24 pp., 7 figs.

TECHNICAL PAPER 17. The effect of stemming on the efficiency of explosives, by W. O. Snelling and Clarence Hall. 1912. 20 pp., 11 figs.

TECHNICAL PAPER 18. Magazines and thaw houses for explosives, by Clarence Hall and S. P. Howell. 1912. 34 pp., 1 pl., 5 figs.

TECHNICAL PAPER 19. The factor of safety in mine electrical installations, by H. H. Clark. 1912. 14 pp.

TECHNICAL PAPER 21. The prevention of mine explosions, report and recommendations, by Victor Watteyne, Carl Meissner, and Arthur Desborough. 12 pp. Reprint of United States Geological Survey Bulletin 369.

TECHNICAL PAPER 22. Electrical symbols for mine maps, by H. H. Clark. 1912. 11 pp., 8 figs.

TECHNICAL PAPER 24. Mine fires, a preliminary study, by G. S. Rice. 1912. 51 pp., 1 fig.

TECHNICAL PAPER 30. Accident prevention at Lake Superior iron mines, by D. E. Woodbridge. 1913. 43 pp., 8 figs.

TECHNICAL PAPER 32. The cementing process of excluding water from oil wells, as practiced in California, by Ralph Arnold and V. R. Garfias. 1912. 10 pp.

TECHNICAL PAPER 38. Wastes in the production and utilization of natural gas, and methods for their prevention, by Ralph Arnold and F. G. Clapp. 1913. 29 pp.

TECHNICAL PAPER 41. Mining and treatment of lead and zinc ores in the Joplin district, Mo., a preliminary report, by C. A. Wright. 1913. 43 pp., 5 figs.

MINERS' CIRCULAR 3. Coal-dust explosions, by G. S. Rice. 1911. 22 pp.

MINERS' CIRCULAR 4. The use and care of mine-rescue breathing apparatus, by J. W. Paul. 1911. 24 pp., 5 figs.

MINERS' CIRCULAR 5. Electrical accidents in mines, their causes and prevention, by H. H. Clark, W. D. Roberts, L. C. Ilsley, and H. F. Randolph. 1911. 10 pp., 3 pls.

MINERS' CIRCULAR 6. Permissible explosives tested prior to January 1, 1912, and precautions to be taken in their use, by Clarence Hall. 1912. 20 pp.

MINERS' CIRCULAR 11. Accidents from mine cars and locomotives, by L. M. Jones. 1912. 16 pp.

MINERS' CIRCULAR 9. Accidents from falls of roof and coal, by G. S. Rice. 1912. 16 pp.

MINERS' CIRCULAR 10. Mine fires and how to fight them, by J. W. Paul. 1912. 14 pp.

